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INTERFACE REQUIREMENTS DOCUMENT (IRD)

FOR THE

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE SERIES R (GOES-R) SYSTEM

SPACE SEGMENT (SS)
TO
GROUND LOCATED - COMMAND, CONTROL, AND COMMUNICATIONS SEGMENT (GL-C3S)

Document No.
417-SeriesR-IRD-0001

January 10, 2005

GOES-R PROJECT OFFICE
NASA GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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SPACE SEGMENT (SS) TO GROUND LOCATED - COMMAND, CONTROL, AND COMMUNCATIONS SEGMENT (GL-C3S)

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1.0 INTRODUCTION

The Geostationary Operational Satellite System Series R (GOES-R) is an operational mission to make observations from geostationary orbit. The GOES-R mission will provide an Advanced Baseline Imager (ABI), Hyperspectral Environmental Suite (HES), Space Environmental In-Situ Suite (SEISS), Solar Imaging Suite (SIS), Geostationary Lightning Mapper (GLM), and communication services for the Data Collection System (DCS), Search and Rescue (SAR) and data relay functions that includes the GOES Rebroadcast (GRB) service, Low Rate Information Transmission (LRIT) service and the Emergency Managers Weather Information Network (EMWIN) service . The five GOES-R mission segments that will interface and function to support the total GOES-R mission are described below. The bold titles are items that are covered in this IRD.

- **Space Segment (SS)**
- **Ground Located - Command, Control, and Communications Segment (GL-C3S)**
- Product Generation and Distribution Segment (PGDS)
- User Interface Segment (UIS)
- Archive and Access Segment (AAS)

The GOES-R Space Segment will also interface with the launch network ground stations.

1.1 Purpose

The purpose of this document is to specify the functional performance interface requirements for the data and RF flow between the GOES-R series satellites and the GOES-R GL-C3S.

This document also provides the basis for subsequent development of interface specific Space Segment and GL-C3S Interface Control Documents (ICDs) by the spacecraft contractor.

1.2 Scope

The interface supports the communication of data between the SS and the GL-C3S. Consequently, this IRD:

- Identifies required communication links between the satellite and the GL-C3
- Establishes functional and performance requirements related to these communication links

The GOES-R system interfaces included in this document are between the GOES-R Spacecraft and Ground Support Equipment elements of the GL-C3 Segment, including support provided by the launch network ground stations. The communication link interfaces between the GOES-R

spacecraft and the auxiliary communication services are found in the associated IRDs [Ref. 21 - 25].

1.3 Applicable Documents

The following documents of the issue listed, or of the issue in effect on the effective date of contract, form a part of this IRD to the extent specified herein. In the event of conflict between documents specified herein and other detailed content of this IRD, this IRD shall be the superseding requirement.

[1] Mission Requirements Document 2 (MRD-2B) for the GOES-R Series dated December 13, 2004

[2] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telemetry Channel Encoding, (CCSDS 101.0-B)

[3] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telecommand Part 1 – Channel Service, (CCSDS 201.0-B)

[4] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telecommand Part 2 – Data Routing Service, (CCSDS 202.0-B)

[5] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telecommand, Part 2.1, Command Operation Procedures, (CCSDS 202.1-B)

[6] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Advanced Orbiting Systems - Networks and Data Links: Architectural Specification, (CCSDS 701.0-B)

[7] ITU Recommendation P.531-7 (2003), Ionospheric Propagation Data and Prediction Methods Required for the Design of Satellite Services and Systems

[8] ITU Recommendation P.581-2 (1990), the Concept of "Worst Month"

[9] ITU Recommendation P.618-8 (2003), Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems

[10] ITU Recommendation P.676-5 (2001), Attenuation by Atmospheric Gases

[11] ITU Recommendation P.679-3 (2001), Propagation Data Required for the Design of Broadcasting-Satellite Systems

[12] ITU Recommendation P.837-4 (2003), Characteristics of Precipitation for Propagation Modeling

[13] ITU Recommendation P.838-2 (2003), Specific Attenuation Model for Rain for Use in Prediction Methods

[14] ITU Recommendation P.839-3 (2001), Rain Height Model for Prediction Methods

[15] ITU Recommendation P.841-3 (2003), Conversion of Annual Statistics to Worst-Month Statistics

[16] National Telecommunications and Information Administration "Manual of Regulations and Procedures for Federal Radio Frequency Management", May 2003 Edition September 2004 Revision

[17] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Packet Telemetry, (CCSDS 102.0-B)

[18] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Packet Telemetry Services, (CCSDS 103.0-B)

[19] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Time Code Formats, (CCSDS 301.0-B)

[20] Consultative Committee for Space Data Systems (CCSDS) Recommendations for Radio Frequency and Modulation Systems, Part 1: Earth Stations and Spacecraft, (CCSDS 401.0-B)

[21] Interface Requirements Document (IRD) for the GOES-R System: Space Segment (SS) to GOES Rebroadcast (GRB) Service, 417-SeriesR-IRD-0002

[22] Interface Requirements Document (IRD) for the GOES-R System: Space Segment (SS) to Low Rate Information Transmission (LRIT) Service, 417-SeriesR-IRD-0003

[23] Interface Requirements Document (IRD) for the GOES-R System: Space Segment (SS) to Emergency Managers Weather Information Network (EMWIN) Service, 417-SeriesR-IRD-0004

[24] Interface Requirements Document (IRD) for the GOES-R System: Space Segment (SS) to Data Collection Service (DCS), 417-SeriesR-IRD-0005

[25] Interface Requirements Document (IRD) for the GOES-R System: Space Segment (SS) to Search and Rescue (SAR) Service, 417-SeriesR-IRD-0006

[26] International Telecommunications Union (ITU) Recommendation ITU-R RA 769-1 of the 1998 Edition of the ITU Regulations for Radio Astronomy

[27] ITU Article S21 of the ITU Radio Regulations RR-S21 described in the 2001 Edition of the ITU Regulations for Power Flux Density Limits

[28] NOAA/NESDIS Antennas and RF Systems Capabilities Handbook, NOAA/OSD3-2001-0043ROUDO, 10 August 2001

Discussion: Document [28] contains information about the RF system capabilities of the NOAA Command and Data Acquisition Stations (CDAS).

The ITU documents described in documents [7] thru [15] contain procedures to be used in calculating link availability and can also be used in determining propagation attenuation.

Applicable document [7] is to be used for scintillation loss. The dash number used for each document is the updated release number. The ITU web site for the documents is http://www.itu.int/publibase/catalog/index.asp

2.0 SYSTEMS RELATIONSHIPS OVERVIEW

2.1 General

The GOES-R Space Segment to GL-C3S interfaces described in this IRD are for the RF interfaces for the Sensor Data Link, CDAS telemetry and command data links and the Ground Network (GN) communication data links that are used during the launch, orbit raising and post-launch operations.

2.2 Missing Requirements

This document contains all GL-C3S RF interfaces except those labeled "TBD" and "TBR". "TBD" (To Be Determined) means that the contractor should determine the missing requirement in coordination with the government. The term "TBR" (To Be Reviewed) implies that the requirement is subject to review for appropriateness by the contractor or the government.

2.3. Definitions

The statements in this document are not of equal importance. The word "shall" designates a requirement. Any deviations from requirements need approval of the NASA contracting officer.

The word "will" designates a statement of fact about the system, its operational environment or the intent of the government.

The word "threshold" is the minimum acceptable performance characteristic

Rationale: MRD-2B, ID Item 1066

The word "goal" is an optimum level of performance, which, if met, could greatly enhance data utility.

Rationale: MRD-2B, ID Item 1067

3.0 PERFORMANCE REQUIREMENTS

3.1 General Requirements

This section contains descriptions of the data flowing between the Space and GL-C3S Segments. The interface is broken down based on the content of the data flow.

Communications Standards shall be Consultative Committee for Space Data Systems (CCSDS) recommendations to the extent that they can be applied without conflict with other requirements of this document.

Rationale: ID item 4663 in MRD-2B

3.1.1 Spacecraft Architecture

The requirements in this IRD are specified for the current notional spacecraft architecture, which relies on a distributed instrument payload allocated to multiple satellites. For consolidated spacecraft architecture, the principal impact is to the Sensor Data (SD) link, which would then consist of the multiplexed sum of the individual A and B Sensor Data links. Table 3.1.1-1 describes the Sensor Data links for the consolidated and distributed spacecraft architectures.

Rationale: The satellite sensor data link requirements for the distributed and consolidated spacecraft architectures are described in ID items 977, 984, 985, and 4390 in the MRD-2B Document.

	Distributed Architecture		Consolidated
Description	"A" Satellite	"B" Satellite	Architecture
Advanced Baseline Imager (ABI)	X		X
Solar Imaging Suite (SIS)			
Solar X-Ray Imager (SXI)	X		X
Solar X-Ray Sensor (XRS)	X		X
Extreme Ultra Violet Sensor (EUVS)	X		X
GOES Lightning Mapper (GLM)	X		X
Magnetometer	X		X
Hyperspectral Environmental Sensor (HES)	X		X
Space Environmental In-Situ Suite (SEISS)	X		X
Magnetospheric Particle Sensor	X		X
Energetic Heavy Ion Sensor	X		X
Solar & Galactic Particle Sensor	X		X
Communication Services			
SD	X	X	X
GRB	X	X	X
LRIT	X	X	X
EMWIN	X	X	X
SAR	X	X	X
DCPI	X	X	X
DCPR	X	X	X
CDA Telemetry and Command	X	X	X
Ground Network T&C and Ranging	X	X	X

Table 3.1.1-1 Data Links for Consolidated and Distributed Spacecraft Architectures

3.1.2 Simultaneous Links

The Space Segment to GL-C3S interface performance requirements shall be met simultaneously for the sensor data downlink in X-band [TBR], the communication service data channels in their respective bands (these interfaces are addressed in separate IRD's [21 – 25], the commanding in S-band [TBR], the telemetry in L-band [TBR], and the telemetry in S-Band [TBR]).

Rationale: The specification described above is a flow down requirement from ID item 4730 in the MRD-2B Document.

3.2 Satellite Sensor Data Channel Downlink

3.2.1 General

The Sensor Data (SD) link is a primary data link that includes all spacecraft components required for the downlink transmission of the combined (multiplexed) on-board instrument data to the NOAA Command and Data Acquisition Station (CDAS).

Rationale: MRD-2B ID Item 4388

The satellite transmit sensor data channel requirements are summarized below in Table 3.2.1-1

Satellite Tx	**Requirement**	**Rationale**
EIRP (dBm)	[TBD]	
Frequency (MHz)	8117.000 [TBR]	MRD-2B ID Item 4402 and CWG recommendation
RF Bandwidth	[TBD]	MRD-2B ID Item 4401
Polarization	Para. 3.2.6	
Tx Multiplexed Data Rate (Mbps)	A satellite: ~ 65 [TBR] B satellite: ~ 67 [TBR]	ID items 4394, 4395, 4396 and 4397 in MRD-2B
Format	NRZ-L [TBR]	
Modulation	Para. 3.2.3	Comm. working group recommendation
Sidelobe level (dB)	-26 [TBR]	Comm. working group recommendation
FEC Coding	Para. 3.2.2	Comm. working group recommendation
BER (may become FER)	1X 10^{-9} at 99.9% link availability (threshold), worst month [TBR]; 1X10^{-10} at 99.9% link availability (goal), worst month[TBR]	ID item 4400 in MRD-2B
Antenna coverage	Para. 3.2.5	
Data randomization	Para. 3.2.4	
Unwanted radiation mask	Para. 3.2.8	
Link margin requirement	Para 3.2.7	
Radio astronomy band	Para 3.2.11	
Power flux density limit	Para. 3.2.12	
CDAS Ground Rx		
Polarization	Para. 3.2.6	
Min. Rx G/T (dB/K)	35 [TBR]	

Rx System Loss (dB)	[TBD]	

Table 3.2.1-1 Sensor Data Link Requirements Summary

3.2.2 Forward Error Correction Coding

A forward error correction (FEC) code such as Low Density Parity Check (LDPC) code will be used for the SD downlink. The selection of a suitable FEC code shall be coordinated with the needs of the data compression scheme, type of modulation used, etc. to ensure the best possible error free data throughput.

Rationale: Recommendation from the Comm. Working group, and also CCSDS [TBD].

3.2.3 Sensor Data Modulation

The Sensor Data modulation that is being considered is Gaussian Minimum Shift Keying (GMSK) [TBR] with $\alpha = 0.5$.

The selection of a suitable modulation shall be coordinated with the needs of the data compression scheme, type of FEC used, etc. to ensure the best possible error free data throughput.

Rationale: Recommendation from the Comm. Working group

3.2.4 Data Randomization

The Sensor Data will be randomized using a PRN sequence consistent with CCSDS Recommendations for Advanced Orbiting Systems - Networks and Data Links: Architectural Specification 701.0-B, Section 5.4.9.1.2.5.

The PRN sequence will be provided in such a way as to facilitate BER measurements on this channel.

Rationale: Recommendation from the communications working group.

3.2.5 Sensor Data Antenna Coverage

The Space to Ground Sensor Data link margin shall be met over earth coverage of at least 200 miles radius.

Rationale: Allows antenna beam to simultaneously cover Wallops and GSFC.

Discussion: If Fairbanks, AK is the backup CDAS, then the antenna must be steerable. Other backup CDAS such as Fairmont, WV may not require a steerable antenna, but rather a shaped beam.

3.2.6 Sensor Data Link Polarization

The Sensor Data link shall be transmitted with switchable Right (RHCP) or Left (LHCP) Hand Circular Polarization .This link will be received at the CDAS with a matching antenna polarization

Rationale: Recommendation from the communications working group.

3.2.7 Link Margin

The Sensor Data link margin shall be a minimum of 3 dB.

Rationale: The link margin described above includes a 2 dB allowance for interference, which is necessary to protect against the steep BER curve, plus 1 dB for unknown and unpredictable causes. The link margin is necessary to sustain the performance of the critical SD link.

3.2.8 Unwanted Radiation Mask

All communication links must comply with paragraph 5.2.2 for frequencies less than 470MHz and 5.6.2 for frequencies above 470 MHz, of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, May 2003 Edition, September 2004 Revision.

Rationale: Compliance is required with NTIA requirements.

3.2.9 Assumed Link Parameters

The following conditions shall be assumed during the calculation of the expected link performance:

1. Propagation impairments for the rain and atmospheric attenuation loss shall be determined by the contractor. The rain and atmospheric attenuation estimates shall be based on the ITU models for the CDAS and back-up CDAS locations. Applicable documents [7] thru [15] shall be used in determining propagation attenuation.

2. Scintillation losses shall be determined by the contractor. The ITU model for the scintillation loss is described in applicable document [7].

3. The worst case antenna elevation angle for the CDAS and backup CDAS's shall be equal to 5 degrees.

4. The link budget loss factor for the worst case polarization mismatch shall be determined by the contractor.

3.2.10 Link Budget Requirement

The spacecraft contractor shall provide the communication link budgets in the ICD for the Sensor Data Link.

Changes to the link budgets shall be documented and reported to the GSFC Communications Subsystem Manager on a monthly basis immediately following the Preliminary Design Review.

Rationale: There is a need to ensure adequate link margins prior to freezing the design and proceeding with the manufacture of flight hardware.

3.2.11 Radio Astronomy Band Protection

The EIRP values for all downlinks shall protect the radio astronomy band from1660.0 to 1670.0 MHz, so that the spectral power flux density in this band at the surface of the earth shall be ≤ -266 dB W/m^2-Hz.

Rationale: Compliance is required with the power flux density requirement for the Radio Astronomy Band as described in the International Telecommunications Union (ITU) Recommendation ITU –R RA 769-1. The ITU specifies a maximum PFD at the ground of -251 dBW/m^2/Hz for the RA band, and this level must be reduced by another 15 dB for geostationary satellites.

3.2.12 Power Flux Density Limits

The downlink EIRP for each data link shall conform to the ITU regulations Section RRS21, Table S21-4 regarding Power Flux Density (PFD) at the surface of the Earth. The communication links shall comply for both the 1.5 MHz and 4 KHz bandwidth at L-Band and 4 KHz at X-Band.

The spacecraft contractor shall notify GSFC if he determines that any transmission channel requires a higher than allowed EIRP to meet the communications data link performance requirements.

The PFD values for each data transmission service shall be defined by the spacecraft contactor and incorporated into the Interface Control document (ICD) thirty days following the Preliminary Design Review and after approval by GSFC.

Rationale: The ITU regulations are described in Article S21 titled “Terrestrial and Space Services Sharing Frequency Bands above 1 GHz” of the ITU Radio Regulation RR-S21. It is to be noted that Siberia has a 24 dB more restrictive power flux density requirement than the backup CDA ground station at Fairbanks, Alaska and this has to be considered in the design of the spacecraft Sensor Data (SD) antenna beam shape.

3.2.13 SD Downlink Description

3.2.13.1 General

The Sensor Data Downlink shall use CCSDS frames, called Coded Virtual Channel Data Units (CVCDUs) in CCSDS 701.0-B. The data frames shall comply with the Multiplexing Service Section 2.3.2.2 of CCSDS 701.0-B-3

The data frames shall be configured as shown in Section 5.4.10.2.d on page 5-65 of CCSDS 701.0-B, with the exceptions described below.

a) Reed-Solomon coding shall not be used so the R-S Check Symbols shown in Section 5.4.10.2.d of CCSDS 701 will be replaced with the parity check bits needed for the actual FEC code chosen for this link.

b) Bitstream Service will not be allowed, so in the “VCDU DATA UNIT ZONE” the designation “M_PDU or B_PDU HDR” shall be changed to “M_PDU HDR”. The designation “M_SDU OR BITS” shall be changed to “M_SDU”, and the designation “R-S CHECK SYMB” shall be deleted.

c) Space link Automatic Repeat Queuing (ARQ) Procedure shall NOT be used.

3.2.13.2 CCSDS Option Required

The VCDU primary header shall comply with Section 5.4.9.2.1.1 Version 2 of CCSDS 701-0-B-3, except the VCDU HEADER ERROR CONTROL shall NOT be used.

Discussion: The VCDU HEADER ERROR CONTROL is not needed because the FEC coding provided by the C&DH will cover the VCDU primary header.

3.2.13.3 Channel Access Data Unit (CADU)

The SD data stream shall include only CADU as described in Section 5.4.10 of CCSDS 701.0-B-3, except the lengths of the CVCDU and the Attached sync Marker may need to be changed to meet the requirements of the FEC coding system chosen for this data link.

3.3 CDAS Telemetry Data Link Requirements

3.3.1 General Requirements

The NOAA Command and Data Acquisition Station (CDAS), the Backup CDA Stations (BUCDAS) and the associated NOAA Satellite Operations Control Center (SOCC) are the primary telemetry interface during normal on-orbit operations.

Rationale: MRD-2B ID Item 4385 and ID Item 4424 that describes the BUCDAS as GSFC and Fairbanks, AK.

The RF interface requirements for the CDAS telemetry data link are summarized in Table 3.3.1-1.

Downlink Tx	**Requirement**	**Rationale**
Nom. EIRP (dBm)	[TBD]	
Freq. (MHz)	1672.000 [TBR]and 1673.000 [TBR]	Comm. Working group recommendation
RF Bandwidth	[TBD]	
Polarization	Para. 3.3.6	
Selectable Data Rate (bit/s)	Para. 3.3.4	
Format	NRZ-M	CCSDS 401.0-B, sec 2.4.2
Modulation	Para. 3.3.5	
Antenna coverage	Para. 3.3.1.2	
FER	$1X\ 10^{-5}$	Comm. working group recommendation
Telemetry Channel Availability	99.9 % for worst month	
FEC coding	Para. 3.3.2	
Data randomization	Para. 3.3.3	
Link margin requirement	Para. 3.3.8	
Radio astronomy band protection	Para. 3.3.11	
Unwanted radiation mask	Para. 3.3.13	
CDAS Rx		
Polarization	Para. 3.3.7	
Rx G/T [dB/K]	26	Heritage spec. from GOES-N,O,P
Receive System Loss [dB]	[TBD]	

Table 3.3.1-1 CDAS Telemetry Link Requirements Summary

3.3.1.1 Telemetry Downlink

The telemetry downlink shall consist of satellite and instrument engineering data, health and safety information, and command receipt verification

The telemetry data will be transmitted at all times the spacecraft is powered on. The amount and types of information available will differ depending upon the operating mode of the spacecraft and instruments.

3.3.1.2 Telemetry and Command Link Antenna Coverage

The spacecraft antenna for the Telemetry, Ranging and Command data links shall provide continuous global coverage of at least 95 % of the 4 pi steradians angle, over which the link shall close with a link margin as described in paragraph 3.3.8.

Continuous global coverage defined as the Earth's surface visible from the spacecraft in geosynchronous orbit with a ground elevation angle of 5 degrees or more.

Rationale: Antenna coverage is required for possible spacecraft contingencies. CDAS station will have circular polarization diversity receive system.

Rationale: Recommendation by the Comm. Working Group.

3.3.2 Forward Error Correction Coding

The forward error correction coding shall be (252,220) Reed-Solomon with interleave depth of 4, concatenated with a 7/8 punctured convolutional code as defined in CCSDS Recommendations for Telemetry Channel encoding 101.0-B-6, Sections 1.2, 2.2, 3.1, 3.2, annex E3.2 [1].

Rationale: ID item 4663 in MRD-2A.

3.3.3 Telemetry Data Randomization

The telemetry data link shall be randomized using a PRN sequence consistent with CCDSD Recommendation for Advanced Orbiting Systems - Networks and Data Links: Architectural Specification 701.0-B, Section 5.4.9.1.2.5.

The PRN sequence will be provided in such a way as to facilitate BER measurements on this channel.

Rationale: Recommendation from the communications working group.

3.3.4 Selectable Telemetry Data Rates

The un-coded telemetry data rate shall be selectable between 4 kbps and 32 kbps.

Discussion: The 32 kbps rate is used during normal on-orbit operations. The 4 kbps rate is used during launch operations and safe-hold mode of operations.

3.3.5 Telemetry Data Modulation

The telemetry data shall be bi-phase-L modulated on the carrier

3.3.6 Telemetry Link Transmit Polarization

The telemetry data link shall be transmitted with Right Hand Circular Polarization (RHCP) [TBR] on the earth facing antenna and LHCP on the anti-earth facing antenna [TBR].

3.3.7 Telemetry Link Receive Polarization

The CDAS telemetry data stream shall be designed for reception by a linearly polarized antenna with a station G/T as described in Table 3.3.1-1, transmitted through the spacecraft RHCP omni directional antenna.

Rationale: Recommendation from the communications working group.

3.3.8 Link Margin Requirement

The telemetry link margins shall be as indicated below.

Operating Mode	Link Margin (dB)
a. Normal operations, station keeping and housekeeping modes	6 dB minimum [TBR]
b. All other modes i.e., storage, safe-hold, etc.	3 dB minimum [TBR]

3.3.9 Assumed Link Parameters

The following conditions shall be assumed during the calculation of the expected link performance.

1. Propagation impairments for the rain and atmospheric attenuation loss shall be determined by the contractor. The rain and atmospheric attenuation estimates shall be based on ITU models for the CDAS and backup CDAS location. Applicable documents [7] through [15] shall be used in determining propagation attenuation.

2. Scintillation losses shall be determined by the contractor. The ITU model for the scintillation loss is described in applicable document [7].

3. The worst case antenna elevation angle for the CDAS and backup CDAS's shall be equal to 5 degrees.

4. The link budget loss for the worst case polarization mismatch shall be determined by the contractor.

3.3.10 Link Budget Requirement

The spacecraft contractor shall provide the communication link budgets in the ICD for the CDAS and backup CDAS telemetry data Links.

Changes to the link budgets shall be documented and reported to the GSFC Communications Subsystem Manager on a monthly basis immediately following the Preliminary Design Review.

Rationale: There is a need to ensure adequate link margins prior to freezing the design and proceeding with the manufacture of flight hardware.

3.3.11 Radio Astronomy Band Protection

The EIRP values for all downlinks shall protect the radio astronomy band from1660.0 to 1670.0 MHz, so that the spectral power flux density in this band at the surface of the earth shall be ≤ -266 dB W/m^2-Hz.

Rationale: Compliance is required with the power flux density requirement for the Radio Astronomy Band as described in the International Telecommunications Union (ITU) Recommendation ITU –R RA 769-1. The ITU specifies a maximum PFD at the ground of -251

dBW/m^2/Hz for the RA band, and this level must be reduced by another 15 dB for geostationary satellites.

3.3.12 Power Flux Density Limits

The downlink EIRP for each data link shall conform to the ITU regulations Section RRS21, Table S21-4 regarding Power Flux Density (PFD) at the surface of the Earth. The communication links shall comply for both the 1.5 MHz and 4 KHz bandwidth at L-Band.

The spacecraft contractor shall notify GSFC if he determines that any transmission channel requires a higher than allowed EIRP to meet the communications data link performance requirements.

The PFD values for each data transmission service shall be defined by the spacecraft contractor and incorporated into the ICD following the PDR and after approval by GSFC.

Rationale: ITU regulations are described in Article S21 titled "Terrestrial and Space Services Sharing Frequency Bands above 1 GHz" of the ITU Radio Regulation RR-S21.

3.3.13 Unwanted Radiation Mask

All communication links must comply with paragraph 5.2.2 for frequencies less than 470MHz and 5.6.2 for frequencies above 470 MHz, of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, May 2003 Edition, September 2004 Revision.

Rationale: Compliance is required with NTIA requirements.

3.4 CDAS Command Data Link Requirements

3.4.1 General

The RF interface requirements for the CDAS Command Data Link are summarized in Table 3.4.1-1.

Uplink Tx	**Requirement**	**Rationale**
Nom. EIRP (dBm)	[TBD]	
Freq. (MHz)	2034.200	Heritage spec. from GOES-N,O,P
RF Bandwidth	[TBD]	
Polarization	Para. 3.4.6	
Command Data Rates (bit/s)	Para. 3.4.2	
Format	NRZ-L	Heritage spec. from GOES-N,O,P
Modulation	Para. 3.4.5	
FEC Coding	Para. 3.4.3	
Satellite Rx		
Polarization	Para. 3.4.7	
Coverage	Para. 3.3.1.2	
Command link G/T (dB/K)	[TBD]	

Dynamic Range [dBmi]	[TBD]	
FER	$1X10^{-5}$	

Table 3.4.1-1 CDAS Command Link Requirements Summary

3.4.2 Command Data Rates

The command uplink data rate will be 1 kbps, 4 kbps or a [TBD] high data rate.

Rationale: The 4 kbps data rate will be used during normal on-orbit operations. The 1 kbps rate will be used during launch operations and safe-hold mode of operations. The high data rate mode will be used to upload ABI and HES memory storage information that is estimated to be approximately 64 megabits [TBR].

3.4.3 Forward Error Correction Coding

The command link will use 64 bit Code Blocks with 56 data bits and an 8 bit BCH error detection code as specified in the CCSDS Recommendations for Telecommand Part 1—Channel Service 201.0-B, Section 3.3.2.

Rationale: MRD-2B ID Item 4663 recommendation for CCSDS compatibility.

3.4.4 Command Data Randomization

The command link will be randomized as specified in the CCSDS Recommendations for Telecommand, Part 1—Channel Service 201.0-B, Section 3.3.1.

Rationale: MRD-2B ID Item 4663 recommendation for CCSDS compatibility.

3.4.5 Command Data Modulation

.The command data shall be BPSK modulated on a subcarrier oscillator frequency of 16 kHz which is phase modulated on the carrier.

Rationale: Recommendation 2.2.2, 2.2.3 and 2.2.4 of CCSDS 401.0-B

3.4.5.1 High Data Rate Command Operations

For the high data rate command link, the command data modulation will be straight BPSK direct on the command link carrier, pre-empting the 1 and 4 kbps operations.

3.4.6 Command Link Transmit Polarization

The command data will be transmitted with Linear Polarization during normal operations. In other operating modes, it will be selectable RHCP/LHCP. In an emergency CP antennas are available.

Rationale: Recommendation from the communications working group.

3.4.7 Command Link Receive Polarization

The command link shall be received at the spacecraft with Right Hand Circular Polarization (RHCP) on the earth facing antenna and LHCP on the anti-earth facing antenna.

Rationale: Communications working group.

3.4.8 Assumed Link Parameters

The following conditions shall be assumed during the calculation of the expected link performance.

1. Propagation impairments for the rain and atmospheric attenuation loss shall be determined by the contractor. The rain and atmospheric attenuation estimates shall be based on ITU models for the CDAS and backup CDAS location. Applicable documents [7] through [15] shall be used in determining propagation attenuation.

2. Scintillation losses shall be determined by the contractor. The ITU model for the scintillation loss is described in applicable document [7].

3. The worst case antenna elevation angle for the CDAS and backup CDAS's shall be equal to 5 degrees.

4. The link budget loss factor for the worst case polarization mismatch shall be determined by the contractor.

3.4.9 Link Budget Requirement

The spacecraft contractor shall provide the communication link budgets in the ICD for the command data links.

Changes to the link budgets shall be documented and reported to the GSFC Communications Subsystem Manager on a monthly basis immediately following the Preliminary Design Review.

Rationale: There is a need to ensure adequate link margins prior to freezing the design and proceeding with the manufacture of flight hardware.

3.5 Ground Network Interface Requirements

3.5.1 General Requirements

The NASA Deep Space Network (DSN) or similar system is the primary interface during the launch and orbit raising phases of the mission.

Rationale: MRD-2B ID Item 4384

The ground network for the launch, orbit raising, and post-launch operations of the GOES-R series satellites is presently in the planning and study phase.

The preliminary telemetry, ranging and command requirements described below are typical performance requirements that are expected to be needed to support the launch, orbit raising and post launch operation of the GOES-R series satellites.

3.5.1.1 Simultaneous Command, Telemetry, and Ranging Operations

The spacecraft shall permit simultaneous command, telemetry and ranging operations to be performed.

Rationale: Recommendation 3.4.1 of CCSDS 401.0-B.

3.5.2 Ground Network Telemetry Requirements

3.5.2.1 General Requirements

The summarized interface requirements for the Ground Network telemetry data link are described in Table 3.5.2.1-1.

S/C Telemetry Downlink	**Requirement**	**Rationale**
Frequency (MHz)	2209.086	Heritage from GOES-N,O,P Program
RF Bandwidth	[TBD]	
Satellite EIRP (dBm)	[TBD]	
End-to-end FER	1×10^{-6}	
FEC coding	Para. 3.3.2	
Data Randomization	Para 3.3.3	
Selectable data rates	Para 3.3.4	
Data format	NRZ-L	Heritage from GOES-N,O,P Program
Data link polarization	Para. 3.3.6	
Link budget requirement	Para.3.3.8	
Radio astronomy band protection	3.3.11	
S/C Antenna coverage	Para. 3.3.1.3	
Power flux density limit	Para. 3.3.12	
Unwanted radiation mask	Para 3.3.13	
Ground Network Rx Requirements		
Ground Network G/T (dB/K)	[TBD]	
Receive system loss (dB)	[TBD}	

Table 3.5.2.1-1 Ground Network Telemetry Data Link Summary

3.5.2.2 Telemetry Downlink

The telemetry downlink shall consist of satellite and instrument engineering data, health and safety information, and command receipt verification. The telemetry data is transmitted from the satellite to the GL-C3S, either through the CDAS or through the launch network ground stations when the satellite is not within view of the CDAS or during a CDAS emergency.

The telemetry data shall be transmitted at all times the spacecraft is powered on. The amount and types of information available will differ depending upon the operating mode of the spacecraft and instruments.

3.5.2.3 Telemetry Data Modulation Structure

For the ground network telemetry link, the telemetry data stream shall be NRZ-L-phase modulated on a 1.024 MHz sine wave sub-carrier frequency, which in turn modulates the ground network transmitter with a nominal modulation index of 1 radian [TBR].

Rational: CCSDS 401.0-B, section 2.4.7

3.5.3 Ground Network Command Link Requirements

3.5.3.1 General Requirements

The summarized interface requirements for the Ground Network telemetry/ranging data link are described in Table 3.5.3-1.

Ground Network Command Uplink	**Requirement**	**Rationale**
Frequency (MHz)	2034.200	Heritage from GOES-N,O,P Program
RF Bandwidth	[TBD]	
Ground Station EIRP (dBm)	[TBD]	
Polarization	Para 3.4.6	Heritage from GOES-N,O,P Program
FEC coding	Para. 3.4.3	
Data randomization	Para. 3.4.4	
Command data rates	Para. 3.4.2	
Link budget requirement	Para 3.4.9	
End-to-end BER	1×10^{-5}	Heritage from GOES-N,O,P Program
Data format	NRZ-L	Heritage from GOES-N,O,P Program
Spacecraft Receive Interface		
Spacecraft G/T (dB/K)	[TBD]	
Receive polarization	Para. 3.4.7	

Table 3.5.3.1-1 Ground Network Command Data Link Summary

3.5.4 Ranging Data Link Requirements

3.5.4.1 General Requirements

The ranging function shall coherently receive, demodulate, re-modulate, and transmit a ground station ranging signal structure while preserving the signal integrity in the presence of noise.

3.5.4.2 Coherent Transponder

The turnaround frequency ratio shall be 221/240 when the receiver is phase locked. When the receiver is not in phase lock, the downlink frequency shall automatically switch to a non-coherent auxiliary oscillator.

Rationale: Recommendation 2.6.1 of CCSDS 401.0-B.

3.5.4.3 Acquisition and Ranging Mode

The ranging threshold shall not be degraded by more than 0.5 dB when the transmitter is turned on. Acquisition shall occur with the with the uplink signal sweeping over a frequency range of +/- 110 kHz [TBR] around the assigned uplink frequency.

Rationale: Heritage requirement from the GOES-N,O,P Program.

APPENDIX A – ABBREVIATIONS AND ACRONYMS

ADS	Archive and Distribution Segment
ATMS	Advanced Technology Microwave Sounder
BCH	Bose-Chaudhuri-Hocquenghem (Forward Error Correction Code)
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
C&DH	Command and Data Handling
C3S	Command, Control and Communications Segment
CDA(S)	Command and Data Acquisition (Station)
CCSDS	Consultative Committee on Space Data Systems
CTV	Compatibility Test Van
CWG	Communications Working Group members from GSFC, Mitretek, MIT/LL
DCPI	Data Collection Platform Interrogate
DCPR	Data Collection Platform Report
DMSP	Defense Meteorological Satellite Program
DSN	Deep Space Network
DSNUG	Deep Space Network Users Guide
EMWIN	Emergency Managers Weather Information Network

EOS	Earth Observation System
GL-C3S	Ground Located - C3 Segment
GLM	GOES Lightning Mapper
GN	Ground Network
GMSK	Gaussian Minimum Shift Keying
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GRB	GOES Rebroadcast
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Hz	Hertz
ICD	Interface Control Document
IDPS	Interface Data Processing Segment
IRD	Interface Requirements Document
ITU	International Telecommunications Union
LDPC	Low Density Parity Check
LEO	Low Earth Orbit
LRIT	Low Rate Information Transmission
LVL2	Level Two
MMC	Mission Management Center
NASA	National Aeronautics and Space Administration
NSA	National Security Agency
NTIA	National Telecommunications and Information Administration
NOAA	National Oceanographic and Atmospheric Administration
NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NRZ-L	Non-Return to Zero – Level
NRZ-M	Non-Return to Zero -- Mark
OQPSK	Offset QPSK (Also referred to as SQPSK – Staggered QPSK)
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PFD	Power Flux Density
QPSK	Quadrature Phase Shift Keying (modulation)
RA	Radio Astronomy
RCT	Real-Time Critical Telemetry
RHST	Real-Time Health and Safety Telemetry

RHT	Real-Time Housekeeping Telemetry
RF	Radio Frequency
RR	Radio Regulation
SAR	Search and Rescue
SD	Sensor Data
SEISS	Space Environment In-Situ Suite
SIS	Solar Imaging Suite
SOC	Satellite Operations Control
SOH(T)	State of Health (Telemetry)
SQPSK	Staggered Quadrature Phase Shift Keying (Also called OQPSK)
SRS	Satellite Requirements Specification (GOES-R)
SS	Space Segment
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TDRSS	NASA Tracking and Data Relay Satellite System